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(54) **HIGH-GAIN MULTICOLOR PIXEL SENSOR
WITH RESET NOISE CANCELLATION**

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(57) **ABSTRACT**

See application file for complete search history.

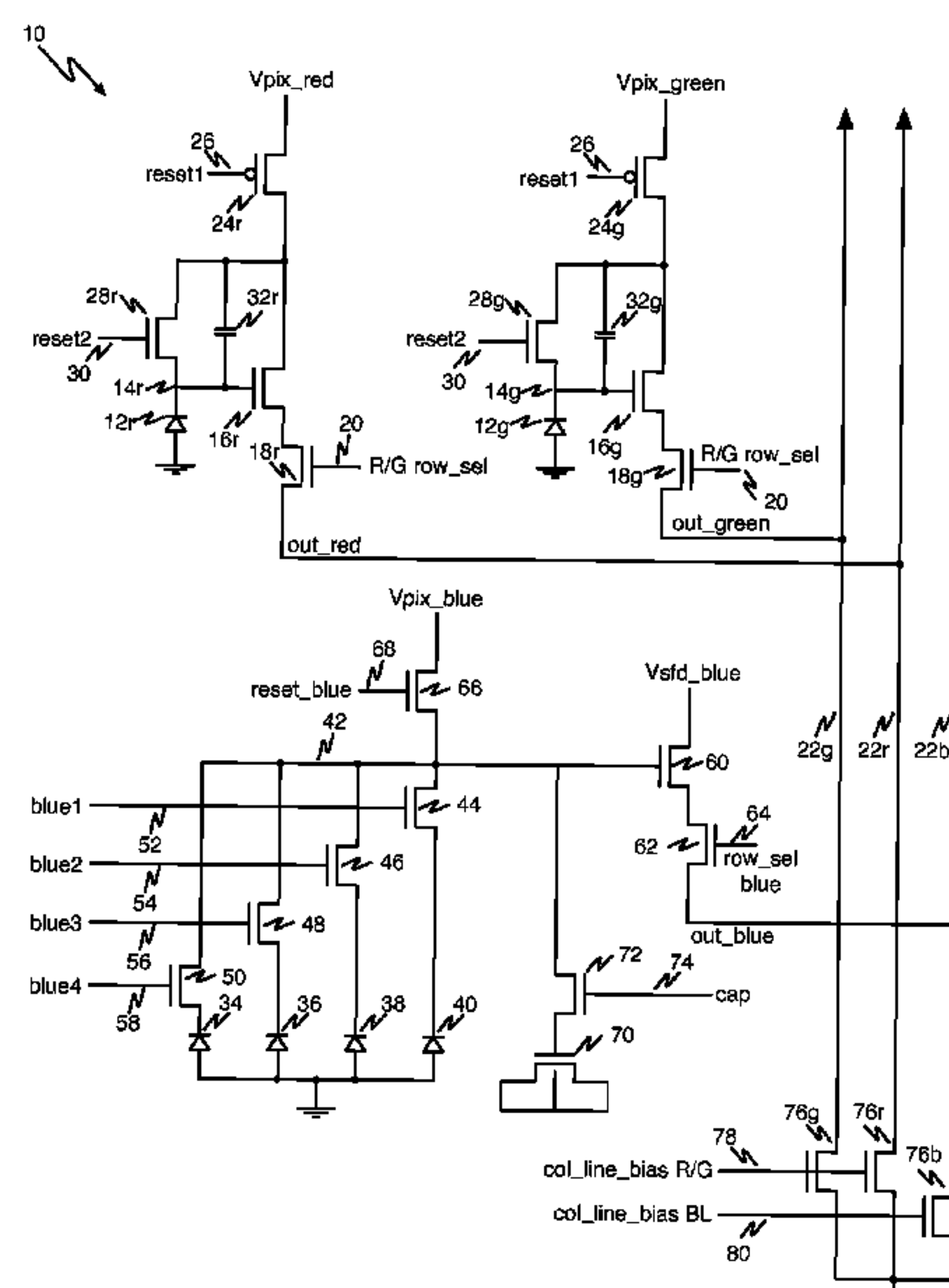
An active CMOS pixel sensor includes a red photodiode and a green photodiode coupled to sense nodes. Blue photodiodes are coupled to a blue sense node through select transistors. A blue reset transistor is coupled between a supply node and the blue sense node. A source-follower transistor is coupled to the blue sense node. A blue row-select transistor is coupled to the source-follower transistor and a biased blue column line. Red and green amplifier transistors have gates coupled to sense nodes, drains coupled to a supply node, and sources. Red and green reset transistors have drains coupled to the drains of the amplifier transistors, sources coupled to the sense nodes. Feedback capacitors couple the sense nodes to the reset transistor drains. Red and green row-select transistors have drains coupled to the sources of the amplifier transistors, sources coupled to biased column lines, and gates coupled to a red-green row-select line.

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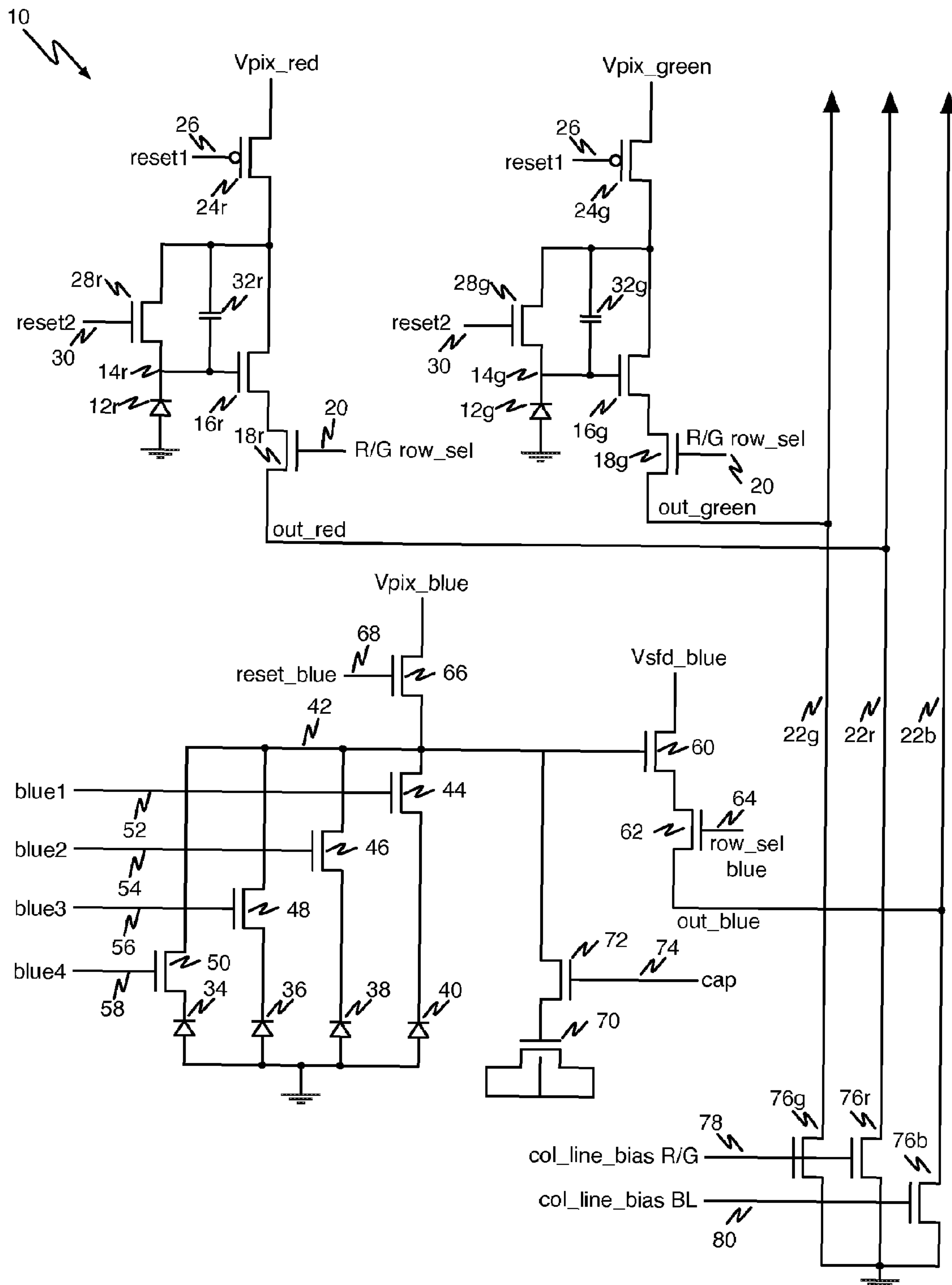


FIGURE 1

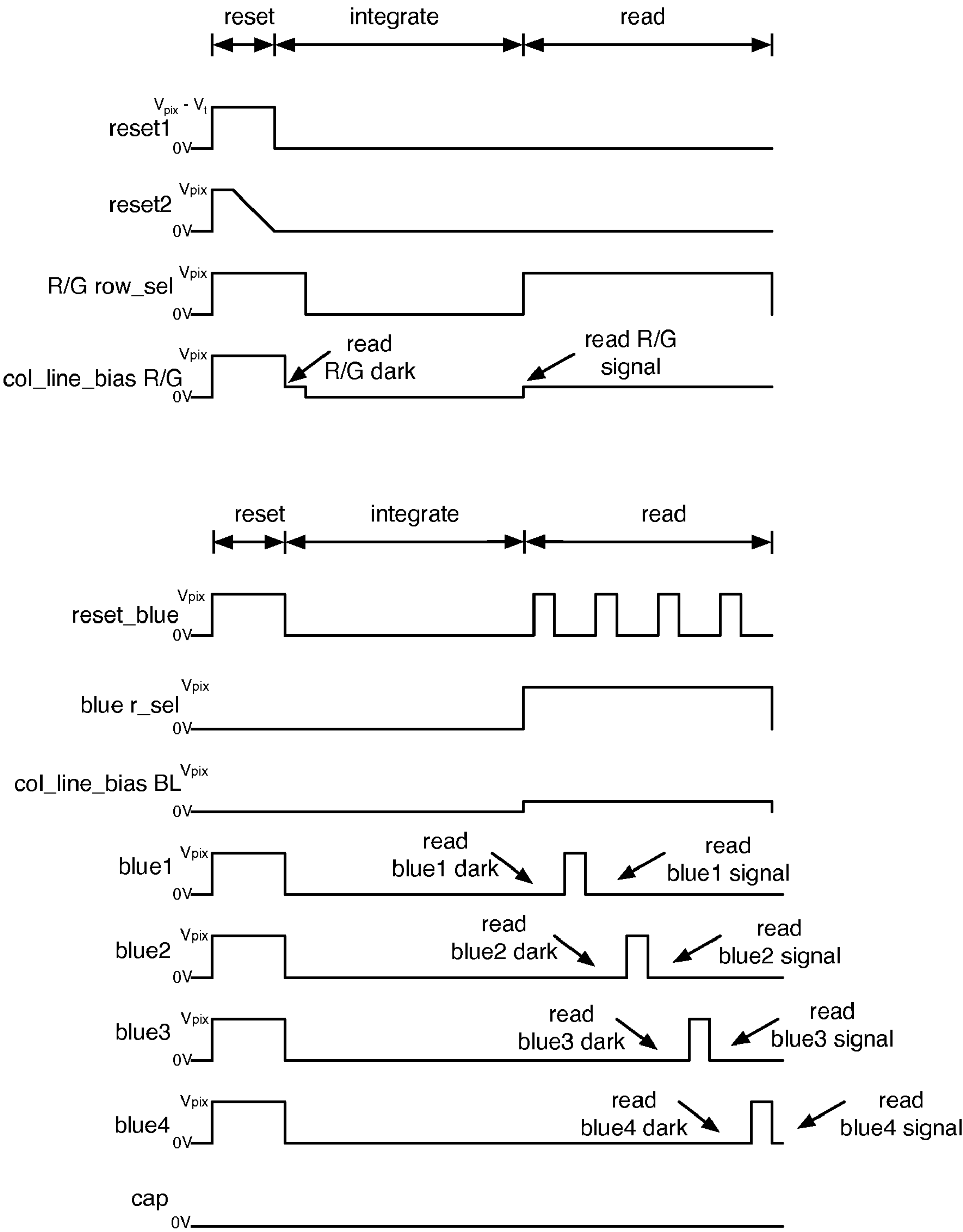


FIGURE 2

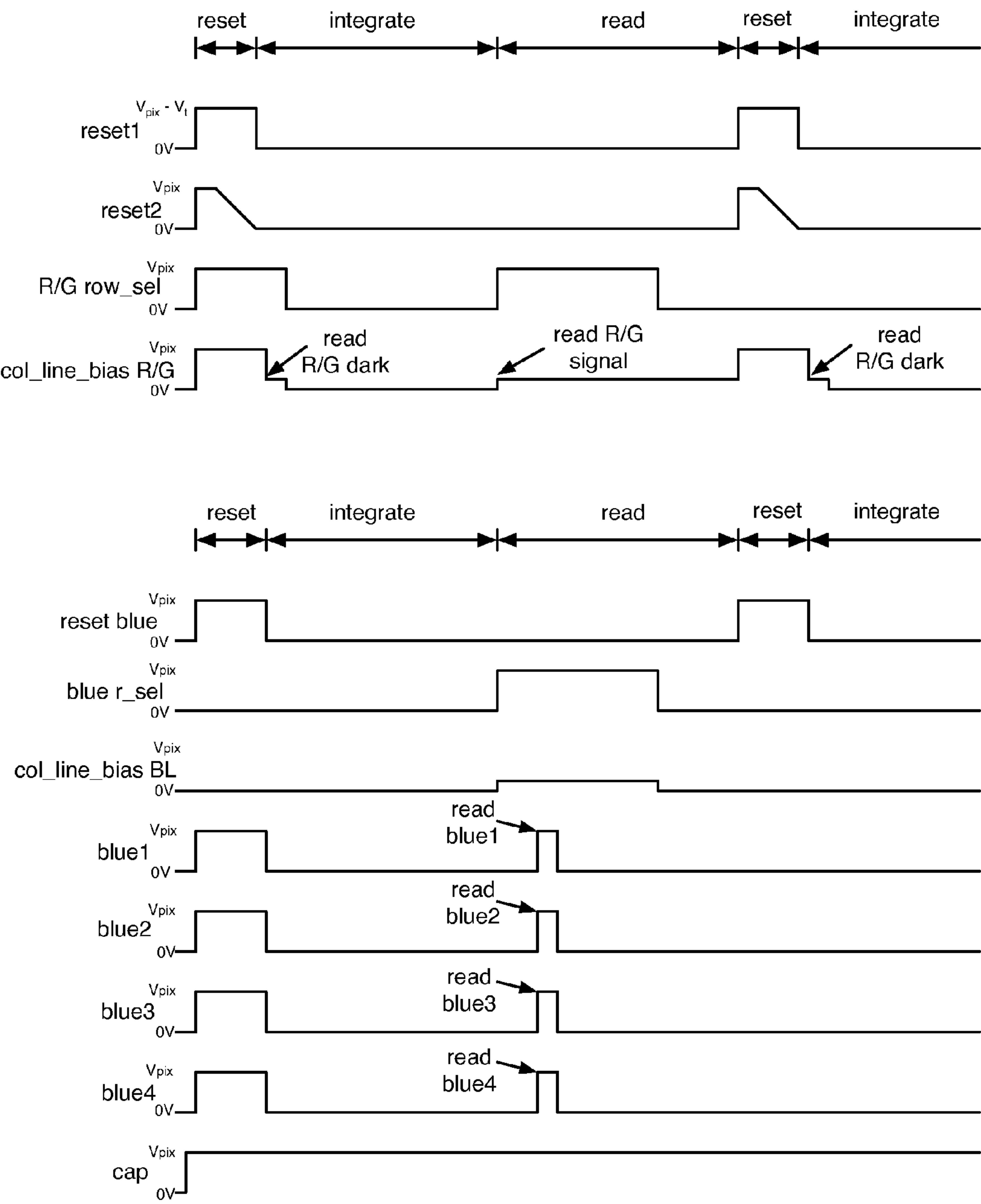


FIGURE 3

HIGH-GAIN MULTICOLOR PIXEL SENSOR WITH RESET NOISE CANCELLATION

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to CMOS pixel sensors and to multicolor CMOS pixel sensors. More particularly, the present invention relates to a high-gain multicolor pixel sensor having reset noise cancellation.

2. The Prior Art

CMOS pixel sensors have become more prevalent in the art. Such pixel sensors typically employ a photodiode to collect charge and a select transistor and source-follower amplifier to read the charge out of the pixel sensor.

Multicolor versions of these pixel sensors are also known. Early examples of such sensors used an array of detectors formed in a pattern such as a Bayer pattern. Recently, vertical-color-filter CMOS pixel sensors have been disclosed, in which multiple pixel sensors (such as blue, green, and red) are positioned at different depths in a semiconductor body to take advantage of the fact that the penetration depth is a function of photon energy. Contact to the detectors disposed beneath the surface of the silicon body is made through deep contact structures.

BRIEF DESCRIPTION OF THE INVENTION

According to one aspect of the present invention, an active CMOS pixel sensor comprises a red photodiode, a green photodiode and a plurality of blue photodiodes. Each of the blue photodiodes coupled to a blue sense node through a different n-channel MOS blue-select transistor through a different blue-select line. An n-channel MOS blue reset transistor has a drain coupled to a supply node, a source coupled to the blue sense node, and a gate coupled to a reset control line. An n-channel MOS blue source-follower transistor has a gate coupled to the blue sense node, a drain coupled to a blue source-follower supply node, and a source. A blue row-select transistor has a drain coupled to the source of the blue source-follower transistor, a source coupled to a blue column output line and a gate coupled to a blue row-select line. A MOS capacitor is coupled to the blue sense node through a capacitor-select transistor having a gate coupled to a capacitor select line. The red photodiode is coupled to a red sense node. An n-channel MOS red amplifier transistor has a gate coupled to the red sense node, a drain, and a source. A p-channel MOS red amplifier transistor has a source coupled to a supply node, a drain coupled to the drain of the n-channel MOS red amplifier transistor, and a gate coupled to a reset1 control line. A n-channel MOS red reset transistor has a drain coupled to the drain of the n-channel MOS red reset transistor, a source coupled to the red sense node, and a gate coupled to a reset2 control line. A red feedback capacitor is coupled between the red sense node and the drain of the n-channel MOS red reset transistor. A red row-select transistor has a drain coupled to the source of the n-channel MOS red amplifier transistor, a source coupled to a red column output line and a gate coupled to a red-green row-select line. The green photodiode is coupled to a green sense node. An n-channel MOS green amplifier transistor has a gate coupled to the green sense node, a drain, and a source. A p-channel MOS green amplifier transistor has a source coupled to a supply node, a drain coupled to the drain of the n-channel MOS green amplifier transistor, and a gate coupled to the reset1 control line. A n-channel MOS green reset transistor has a drain coupled to the drain of the n-channel MOS green reset transistor, a

source coupled to the green sense node, and a gate coupled to the reset2 control line. A green feedback capacitor is coupled between the green sense node and the drain of the n-channel MOS green reset transistor. A green row-select transistor has a drain coupled to the source of the n-channel MOS green amplifier transistor, a source coupled to a green column output line and a gate coupled to the red-green row-select line. The blue, red, and green column output lines are each coupled, respectively, to a blue, red, and green column-line bias transistor. The gate of the blue column-line bias transistor is coupled to a blue column line bias control line. The gates of the red and green column-line bias transistor are coupled to a R/G column line bias control line.

BRIEF DESCRIPTION OF THE DRAWING FIGURES

FIG. 1 is a schematic diagram of an illustrative multicolor CMOS active pixel sensor according to one aspect of the present invention.

FIG. 2 is a timing diagram that illustrates one method for operating the pixel sensor of FIG. 1.

FIG. 3 is a timing diagram that illustrates another method for operating the pixel sensor of FIG. 1.

DETAILED DESCRIPTION OF THE INVENTION

Persons of ordinary skill in the art will realize that the following description of the present invention is illustrative only and not in any way limiting. Other embodiments of the invention will readily suggest themselves to such skilled persons.

Referring now to FIG. 1, a schematic diagram providing an example of such a pixel sensor **10** is shown. Pixel sensor **10** is configured so that the entire array can be reset at once. A pixel sensor of this type is usefully employed in an SLR-shutter type of pixel sensor array.

A red photodiode **12_r** is coupled to a sense node **14_r** comprising the gate of n-channel MOS amplifier transistor **16_r**. The source of n-channel MOS amplifier transistor **16_r** is coupled to the drain of an n-channel MOS row-select transistor **18_r**. The gate of n-channel MOS red row-select transistor **18_r** is coupled to R/G row-select line **20**. The source of n-channel MOS red row-select transistor **18_r** is coupled to column output line **22_r**.

The drain of n-channel MOS amplifier transistor **16_r** is coupled to the drain of p-channel MOS amplifier transistor **24_r**. The source of p-channel MOS amplifier transistor **24_r** is coupled to supply potential V_{pix_red} . The gate of p-channel MOS amplifier transistor **24_r** is coupled to a reset1 line **26**.

An n-channel MOS reset transistor **28_r** is coupled between the gate of n-channel MOS amplifier transistor **16_r** and the common connection of the drain of p-channel MOS amplifier transistor **24_r** and the drain of n-channel MOS amplifier transistor **16_r**. The gate of n-channel MOS reset transistor **28_r** is coupled to a reset2 line **30**. A capacitor **32_r** is coupled between the red sense node **14_r** and the common connection of the drain of n-channel MOS amplifier transistor **16_r** and the drain of p-channel MOS amplifier transistor **24_r**.

Similarly, a green photodiode **12_g** is coupled to a green sense node **14_g** comprising the gate of n-channel MOS amplifier transistor **16_g**. The source of n-channel MOS amplifier transistor **16_g** is coupled to the drain of an n-channel MOS row-select transistor **18_g**. The gate of n-channel MOS red row-select transistor **18_g** is coupled to R/G row-select line **20**. The source of n-channel MOS red row-select transistor **18_g** is coupled to a column output line **22_g**.

3

The drain of n-channel MOS amplifier transistor **16g** is coupled to the drain of p-channel MOS amplifier transistor **24g**. The source of p-channel MOS amplifier transistor **84g** is coupled to supply potential V_{pix_green} . The gate of p-channel MOS amplifier transistor **24g** is coupled to reset1 line **26**.

An n-channel MOS reset transistor **28g** is coupled between the gate of n-channel MOS amplifier transistor **16g** and the common connection of the drain of p-channel MOS amplifier transistor **24g** and the drain of n-channel MOS amplifier transistor **16g**. The gate of n-channel MOS reset transistor **28g** is coupled to reset2 line **30**. A capacitor **32g** is coupled between the sense node **14g** and the common connection of the drain of n-channel MOS amplifier transistor **16g** and the drain of p-channel MOS amplifier transistor **84g**.

Blue photodiodes **34**, **36**, **38**, and **40** are coupled to a blue sense node **42** through blue-select transistors **50**, **48**, **46**, and **44**, respectively. The gate of blue-select transistor **44** is coupled to a blue1 select line **52**; the gate of blue-select transistor **106** is coupled to a blue1 select line **114**; the gate of blue-select transistor **48** is coupled to a blue1 select line **56**; and the gate of blue-select transistor **40** is coupled to a blue1 select line **58**.

N-channel MOS amplifier transistor **60** has its gate coupled to blue sense node **42**. The drain of n-channel MOS amplifier transistor **60** is coupled to supply potential V_{sfd_blue} . The source of n-channel MOS amplifier transistor **60** is coupled to the drain of n-channel MOS blue row select transistor **62**. The source of n-channel MOS blue row select transistor **62** is coupled to column output line **22b**. The gate of n-channel MOS blue row select transistor **62** is coupled to blue row select line **64**.

N-channel MOS reset transistor **66** has its source coupled to blue sense node **42** and its drain coupled to supply potential V_{pix_blue} . Its gate is coupled to reset_blue line **68**. Blue sense node **42** is also coupled to MOS capacitor **70** through n-channel MOS capacitor transistor **72**. The gate of n-channel MOS capacitor transistor **72** is coupled to capacitor line **74**.

The red, green, and blue column output lines **22r**, **22g**, and **82b** are each coupled to the drain of a respective n-channel MOS column output load transistor **76r**, **76g**, and **76b**. The gates of n-channel MOS column output load transistors **76r** and **76g**, are coupled together to a column_bias line R/G **78**. The gate of n-channel MOS column output load transistor **76b** is coupled to a column_bias line BL **80**. The sources of n-channel MOS column output load transistors **76r**, **76g**, and **76b** are coupled together to ground.

Referring now to FIG. 2, a timing diagram illustrates a method of operating the pixel sensor **10** of FIG. 1. First, the signal reset2 is asserted. Then the n-channel MOS column output load transistors **76r**, **76g**, and **76b** are turned on. The red and green row-select signals are asserted. The reset1 line is biased to a voltage level just slightly higher than the V_t of the p-channel MOS amplifier transistors **24r** and **24g** to just barely turn them on. At this point in time, transistor pairs **16r** and **84r** and **16g** and **24g** each form an amplifier. The reset2 signal is ramped down and negative feedback through capacitors **32r** and **32g** act to cancel any reset noise in the amplifiers.

Next, photocharge is integrated on the red, green, and blue photodiodes. The signal reset1 is turned on hard to place the potential V_{pix} at the drains of transistors **16r** and **16g** to cause them to operate as source-follower amplifiers. The red, green, and blue row select transistors are turned on and the red, green and blue bias transistors are tuned on as current source loads.

According to one aspect of the present invention, depicted in FIG. 2, the four blue signals are read out individually. The blue row select transistor is turned on and the blue column line bias transistor is turned on to provide a bias level and the

4

blue1, blue2, blue3, and blue4 signals are individually asserted. The reset_blue signal is asserted in between each of the blue1, blue2, blue3, and blue4 signals in order to clear the previous signal from the common node.

As shown in FIG. 2, the red and green channels may also be read prior to the start of photointegration to generate a red dark and a green dark signal. The red dark signal and the green dark signal may then be subtracted from the red and green signals that are read after photo integration in order to cancel any effects due to the variation in the reset levels of the red and green channels.

According to another aspect of the present invention depicted in FIG. 3, the pixel sensor is operated in a mode in which the four blue signals are read out simultaneously. In this mode, the signal "cap" is asserted on line **74** to add the capacitance of MOS capacitor **70** to the capacitance of sense node **42** in order to prevent the combined blue signals from overwhelming the capacitance of the blue sense node **42**. As shown in FIG. 3, "dark" readings may also be taken in the red and green channels to compensate for the variation in the reset levels of the red and green channels.

While embodiments and applications of this invention have been shown and described, it would be apparent to those skilled in the art that many more modifications than mentioned above are possible without departing from the inventive concepts herein. The invention, therefore, is not to be restricted except in the spirit of the appended claims.

What is claimed is:

1. A CMOS active pixel sensor comprising:

a red photodiode coupled to a red sense node;

a green photodiode coupled to a green sense node;

a plurality of blue photodiodes, each blue photodiode coupled to a blue sense node through a different n-channel MOS blue-select transistor having a gate coupled to a different blue select line;

an n-channel MOS blue reset transistor having a drain coupled to a supply node, a source coupled to the blue sense node, and a gate coupled to a reset control line;

an n-channel MOS source-follower transistor having a gate coupled to the blue sense node, a drain coupled to a source-follower supply node, and a source;

a blue row-select transistor having a drain coupled to the source of the source-follower transistor, a source coupled to a blue column output line and a gate coupled to a blue row-select line;

an n-channel MOS red amplifier transistor having a gate coupled to the red sense node, a drain coupled to a supply node, and a source;

an n-channel MOS red reset transistor having a drain coupled to the drain of the n-channel MOS red amplifier transistor, a source coupled to the red sense node, and a gate coupled to a reset2 control line;

a red feedback capacitor coupled between the red sense node and the drain of the n-channel MOS red reset transistor;

a red row-select transistor having a drain coupled to the source of the n-channel MOS red amplifier transistor, a source coupled to a red column output line and a gate coupled to a red-green row-select line;

an n-channel MOS green amplifier transistor having a gate coupled to the green sense node, a drain coupled to a supply node, and a source;

an n-channel MOS green reset transistor having a drain coupled to the drain of the n-channel MOS green amplifier transistor, a source coupled to the green sense node, and a gate coupled to the reset2 control line;

5

a green feedback capacitor coupled between the green sense node and the drain of the n-channel MOS green reset transistor; and

a green row-select transistor having a drain coupled to the source of the n-channel MOS green amplifier transistor, a source coupled to a green column output line and a gate coupled to the red-green row-select line.

2. The CMOS active pixel sensor of claim 1 further including a MOS capacitor coupled to the blue sense node through a capacitor-select transistor having a gate coupled to a capacitor select line.

3. The CMOS active pixel sensor of claim 1 further including:

a p-channel MOS red amplifier transistor having a source coupled to a voltage-supply node, a drain coupled to the drain of the n-channel MOS red amplifier transistor, and a gate coupled to a red reset1 control line; and

a p-channel MOS green amplifier transistor having a source coupled to a voltage-supply node, a drain coupled to the drain of the n-channel MOS green amplifier transistor, and a gate coupled to a green reset1 control line.

4. The CMOS active pixel sensor of claim 3 wherein the red reset1 control line and the green reset1 control line are common.

5. The CMOS active pixel sensor of claim 1 wherein the blue, red, and green column output lines each coupled, respectively, to a blue, red, and green column-line bias transistor, the gate of the blue column-line bias transistor coupled to a blue column line bias control line, and the gates of the red and green column-line bias transistor coupled to a R/G column line bias control line.

6. A CMOS active pixel sensor comprising:

a red photodiode coupled to a red sense node;

a green photodiode coupled to a green sense node;

6

a plurality of blue photodiodes, each blue photodiode coupled to a blue sense node through a different n-channel MOS blue-select transistor having a gate coupled to a different blue select line;

an n-channel MOS blue reset transistor having a drain coupled to a supply node, a source coupled to the blue sense node, and a gate coupled to a reset control line;

an n-channel MOS source-follower transistor having a gate coupled to the blue sense node, a drain coupled to a source-follower supply node, and a source;

a blue row-select transistor having a drain coupled to the source of the source-follower transistor, a source coupled to a blue column output line and a gate coupled to a blue row-select line;

an n-channel MOS red amplifier transistor configured to cancel reset noise during a reset period and to act as a source-follower during a readout period;

a red row-select transistor having a drain coupled to the source of the n-channel MOS red amplifier transistor, a source coupled to a red column output line and a gate coupled to a red-green row-select line;

an n-channel MOS green amplifier configured to cancel reset noise during a reset period and to act as a source-follower during a readout period; and

a green row-select transistor having a drain coupled to the source of the n-channel MOS green amplifier transistor, a source coupled to a green column output line and a gate coupled to the red-green row-select line.

7. The CMOS active pixel sensor of claim 6 wherein the blue, red, and green column output lines each coupled, respectively, to a blue, red, and green column-line bias transistor, the gate of the blue column-line bias transistor coupled to a blue column line bias control line, and the gates of the red and green column-line bias transistor coupled to a R/G column line bias control line.

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